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ABSTRACT

This training module on the troubleshooting of an electromechanical system, The Westinghouse Programmable Logic Controller (PLC) controlling a pneumatic robot, is used for a troubleshooting unit in an electromechanical systems/robotics and automation systems course. In this unit, students locate and repair a defect in a PLC-operated machine. The module contains a description, objective, content outline, student activities, methodology, and nine resources. The content outline contains the following units: safety procedures; determining normal system operation; determining point of system failure; analyze data; use PLC override to confirm determination; did something occur to change drum data; repair; verification of repair; and troubleshooting report. There are eight student activities: take pretest; read chapter; read a section in the equipment manual; attend lecture/demonstration; perform laboratory exercises using supplied worksheet; complete report; take posttest; and complete evaluation. The following materials are provided: student packet, student worksheet evaluation for exercise, and eight pages of machine-specific reference data useful in troubleshooting the system. (NLA)

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ED347369

# High-Technology Training Module

Module Title: TROUBLESHOOTING OF AN ELECTROMECHANICAL SYSTEM (WESTINGHOUSE PLC CONTROLLING A PNEUMATIC ROBOT)

Unit: TROUBLESHOOTING

Course: ELECTROMECHANICAL SYSTEMS AND ROBOTICS AND AUTOMATION SYSTEMS

Grade Level (s): POSTSECONDARY

Developed by: JAMES D. TUCKER

Date: FALL 1989

School: NORTHCENTRAL TECHNICAL COLLEGE

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Developed as a part of the High-Technology Training Model for Rural Based Business and Industry, Technical Colleges and Local and State Educational Agencies under Grant No. V199A90151.

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HIGH TECHNOLOGY TRAINING MODULE

TITLE - "Electromechanical Troubleshooting"

Description- The Electromechanical Troubleshooting module fits into a course called Electromechanical Systems and Robotics. This is a fourth semester, technical college course for Electromechanical Technology majors. The course takes a systems approach to teaching automation and robotics. The module is a response to industry's request for technicians that can troubleshoot systems and use sound reasoning to solve problems.

The module will also be used in course called Automation Systems. This is an elective course for Electronics and Laser students.

Before the module is attempted, the student must have demonstrated a fundamental knowledge of Ladder Logic, PLC operation and programming, and the operation of the test machine, a pneumatic robot. The student must also be familiar with the use of test equipment.

Name- Jim Tucker, Electromechanical Instructor

School- Northcentral Technical College
Wausau, Wisconsin

Module
Objective- Given correct documentation and a voltmeter, and a PLC progrmming station, students will locate and repair a defect in a Programmable Logic Controller (PLC) operated machine. They will be evaluated as to the method used, organization and time required. Finally, the student will write a report of the procedure.

CONTENT OUTLINE

TROUBLESHOOTING AN ELECTROMECHANICAL SYSTEM

I. Safety Procedures.

A. Neccessity of working on energized circuits.

1. What ifs involved with a hot circuit.

2. Need to be able to predict the actions of the machine.

B. Safety procedures for protection of the machine and the troubleshooter.

1. Safety glasses.

2. One hand in pocket.

3. Don't energize any switches or sensors just to "see what would happen".

4. Correct use of meters.

5. Working with a partner.

6. Consequences of using the PLC "Force" mode.

II. Determining Normal System Operation.

A. Correct documentation.

1. Schematic diagram of the system.

2. PLC ladder diagram.

3. Drum program.

4. Sequence or timing chart.

III. Determining Point of System Failure.

A. Operate system while viewing PLC in monitor mode.

B. View inputs and outputs while the system operates.

C. Determine the point at which the systems deviates from expected operational sequence.

D. Record results.

IV. Analyze data.

A. Compare actual results with expected results.

B. List possible causes of the problem.

1. Hardware.
2. Software.
3. Interface.
4. Power.
5. Mechanical.

C. Determine most likely cause.

D. Record this determination.

V. Use PLC over-ride to confirm determination.

A. Force contact?

B. Force coil?

C. Analyze result.

VI. Did something occur to change drum data?

VII. Repair.

A. Tighten loose connection.

B. Repair or replace faulty part.

C. Realign or adjust limit sensors.

D. (For the purposes of this exercise fault switches are turned off to restore correct operation.)

VI. Verification of repair.

A. Run process viewing system in PLC monitor mode.

B. Compare actual operation with predicted operation.

C. If actual and predicted operation are the same, consider repair a success. If a problem still exists, redo Step IV.

VII. Troubleshooting report.

A. Fill out troubleshooting report.

1. Name.
2. Date.
3. Machine name and number.
4. Analysis of problem.
5. Corrective action taken.

## STUDENT ACTIVITIES

I. Take Pretest.

A. Results of Pretest are not discussed with students.

II. Read Rexford Chapter 15, "Troubleshooting".

III. Read Westinghouse PC-1100 Systems Manual Section 8 "Troubleshooting".

IV. Attend a lecture/demonstration on troubleshooting.

V. Using the worksheet supplied, perform lab exercise.

A. Determine correct system operation.

B. Determine current operation of defective system.

C. Analyze data.

D. Identify the defect.

E. Repair circuit. (This will be simulated since the defect is actually a fault switched in by the instructor.)

6. Complete troubleshooting report.

7. Take Post Test. Same as pretest. (May be different)

8. Fill out evaluation from Stout.

## METHODOLOGY

1. Prepare Pretest/Post test on troubleshooting.

2. Prepare for presentation a lecture on troubleshooting.

3. Write a troubleshooting assumptions and procedures handout.
   (Summery of lecture.)

4. Write a troubleshooting worksheet.

5. Design and setup a machine process using a PLC and a pneumatic trainer. Hidden switches will be used to insert system faults. Interface the PLC system with an electric robot.

6. Determine the correct operational sequence under working conditions.

7. Develop a troubleshooting report form.

8. Develop a student evaluation form.

9. Gather together all documentation that is required to troubleshoot the system. Include; programs, ladder diagrams, wiring and connector charts, and operational sequences.

RESOURCES

Author: Kenneth B. Rexford

Title : Electrical Control For Machines, 3rd edition

Source: Delmar Publishers Inc., 1987

Author: Westinghouse Electric Corporation

Title : Numa-Logic PC-1100 Micro Programmable Controller Systems Manual

Source: Westinghouse Electric Corporation, 1983

Author: Ahlers, R.H. and others

Title : Special Issue on Special Systems for Department of Defense Training.

Source: Journal of Computer Based Instruction; v13 n2 p2-61 Spring 86

Author: Morrow, Rick and Humler, John

Title : Applied Industrial Electronics: Power Control and Electronic Troubleshooting.

Source: Oklahoma State Board of Vocational and Technical Education, Stillwater. Curriculum and Instructional Materials Center. 1985

Author: Knerr, Bruce and others
Title : Computer-based Simulations for Maintenance Training: Current ARI Research. Technical Report 544.

Source: Army Research Inst. for the Behavioral and Social Sciences, Alexandria, Va. 1979

Author: Swanson, Richard A. and Sisson, Gary R.

Title : Analysis of Process and Troubleshooting Work Behavior.

Source: Performance and Instruction Journal, 1983, Vol. 22,#2 Pg-19-22

Author: Long, William E.

Title : Getting Started in Electronic Troubleshooting.

Source: Reston Publishing Co. Inc., 1979.

Author: Woods, Donald R.

Title : Novice Versus Expert Research.

Source: Journal of College Science Teaching, December 1988/ January 1989.

Author: Metzger, Daniel L.

Title : Electronic Components, Instruments, and Troubleshooting.

Source: Prentice-Hall Inc., 1981

THE FOLLOWING FIVE PAGES MAKE UP THE PACKET THE STUDENT RECIEVED

## TROUBLESHOOTING ASSUMPTIONS

1. Assume that the equipment once worked properly. Design, components and wiring connections are all correct.

2. Assume that only one problem exists.

3. Test equipment and the tested circuit works according to theory. If it doesn't seem to, you have overlooked something.

4. The troubleshooter's time is important. You must constantly weigh choice of instruments, sequence of procedures, availability of parts, etc.

## TROUBLESHOOTING TIPS

1. Do you know how it is supposed to operate?

2. Do you have a schematic?

3. Is it under warranty?

4. Check the obvious things first.

PLC SYSTEM TROUBLESHOOTING WORKSHEET

System Name_____

Your Name_____

PLC Program Name_____

Robot Program Name_____

Initials

I. Review safety procedures. _____

II. Determine normal system operation. _____

A. Get the correct documentation

1. Schematic diagram of the system.
2. PLC ladder diagram.
3. Microbot program.
4. Drum data both timer and pneumatic robot.

III. Determine point of system failure. _____

A. Operate system while viewing PLC in the monitor mode.

B. Note inputs and outputs.

C. Determine the point at which the system system deviates from expected sequence.

D. Record results._____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

IV. Analyze data. _____

A. Compare actual results with expected results.

_____
_____
_____
_____
_____

B. List possible causes of the problem.

_____
_____
_____
_____
_____
_____

C. Determine the most likely cause.

_____
_____
_____
_____
_____
_____

V. Confirm your analysis of failure. _____

A. Use force mode. _____
_____
_____

B. Use voltmeter to check for correct voltages.

_____
_____
_____

C. Reload Microbot program? _____
_____
_____

D. Review drum data. _____
_____
_____

E. Use space below to note other method you used.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

VI. Make the repair. _____

A. Note your action below.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

VII. Verify the repair. _____

A. Run process viewing PLC in the monitor mode.

B. Compare actual operation with predicted operation.

C. If actual and predicted operation are the same, consider the repair a success. If a a problem still exists, redo starting at Step IV.

VIII. Fill out troubleshooting report. _____

TROUBLESHOOTING REPORT

Date_____
Name_____
System_____
Computer Program Names_____
_____
_____

1. Describe the problem. _____
_____
_____
_____
_____
_____

2. Describe your analysis procedure. _____
_____
_____
_____
_____
_____

3. Corrective action taken. _____
_____
_____
_____
_____
_____
_____
_____

4. Parts required._____
_____
_____
_____
_____
_____
_____

5. Program changes made._____
_____
_____
_____
_____
_____
_____

6. Your Signature. _____

THE FOLLOWING IS A WORKSHEET USED TO EVALUATE THE STUDENTS AS THEY PERFORMED THE TROUBLESHOOTING EXERCISE

PLC TROUBLESHOOTING

PROCESS EVALUATION FORM

1. Students Name(s)_____
_____

2. Date_____

3. Start Time_____

4. End Time_____

5. Total Time_____

6. Fault(s) inserted. (One at a time only.)

_____
_____
_____
_____

7. Each found? yes or no List any not found.

_____
_____
_____
_____

8. Statement of evaluation.

Student 1._____
_____
_____
_____
_____
_____
_____
_____
_____

Student 2._____
_____
_____
_____
_____
_____
_____
_____
_____

THE FOLLOWING PAGES ARE THE MACHINE SPECIFIC REFERENCES REQUIRED FOR THE STUDENTS TO TROUBLESHOOT THE SYSTEM.

PLC AND PNEUMATIC TROOUBLESHOOTING MODULE

```
-----------------------------------------------------------------------------
WESTINGHOUSE  NUMA-LOGIC LADDER PRINTOUT V5.0  0001 REF. NO. 0000

0!START                                                  +------------+       !
0!IN0002 CR0033 IN0010                                   !            !TT0010!
0!--] [----]\[----]\[-----------------------------------!PRESET      !--( )-!
1!                                                       !HR0100      !       !
 !TT0010                                                 !            !       !
 !--]\[-------------------------------------------------!            !       !
 !                                                       !            !       !
 !                                                       !ACTUAL      !       !
 !                                                       !HR0101      !       !
 !                                                       !            !       !
 !                                                       +------------+       !
0!                                                       +------------+       !
0!IN0001                                                 !            !MV0050!
0!--] [-------------------------------------------------!SOURCE      !--( )-!
2!                                                       !OG0002      !       !
 !                                                       !            !       !
 !                                                       !DESTINATION !       !
 !                                                       !HR0200      !       !
 !                                                       !            !       !
 !                                                       +------------+       !
0!                                                       +------------+       !
0!IN0001                                                 !            !MV0051!
0!--] [-------------------------------------------------!SOURCE      !--( )-!
3!                                                       !IG0001      !       !
 !                                                       !            !       !
 !                                                       !DESTINATION !       !
 !                                                       !HR0201      !       !
 !                                                       !            !       !
 !                                                       +------------+       !
0!BP0006                                                                      !
0!HR0200                                                                CR0033!
0!--] [-+-----------------------------------------------------------------( )-!
4!BP0007!                                                                     !
 !HR0200!                                                                     !
 !--] [-+                                                                     !
 !                                                                            !
 !                                                                            !
0!       BP0012 BP0012                                                        !
0!CR0033 HR0200 HR0201                                                  CR0034!
0!--] [-+--] [----] [-+-----------------------------------------------------( )-!
5!      !BP0013 BP0013!                                                       !
 !      !HR0200 HR0201!                                                       !
 !      +--] [----] [-+                                                       !
 !      !BP0014 BP0014!                                                       !
 !      !HR0200 HR0201!                                                       !
 !      +--] [----] [-+                                                       !
 !      !BP0015 BP0015!                                                       !
 !      !HR0200 HR0201!                                                       !
 !      +--] [----] [-+                                                       !
 !      !BP0016 BP0016!                                                       !
 !      !HR0200 HR0201!                                                       !
 !      +--] [----] [-+                                                       !
```

GENERAL TIMER

MOVE DRUM #11 INFORMATION INTO HR SO THAT IT CAN BI BIT PICKED

MOVE LIMIT SWITCH INFO. SO THAT IT CAN BE BIT PICKED

STOPS TIMER DURING TRANSLATE

PULSES DRUM TC NEXT POSITION WHEN TRAVERSE LIMIT SWITCH AND REQUIRED POSITION ARE BOTH TRUE

```
-----------------------------------------------------------------------------
WESTINGHOUSE  NUMA-LOGIC LADDER PRINTOUT V5.0  0002 REF. NO. 0000

0!                                                      +------------+       !
0!TT0010 IN0010                                         !            !DR0011! MASTER
0!--] [-+--]\[-------------------------------------------!NO. OF STEPS!--( )-! DRUM
6!      !                                               !  0009      !       !
 !CR0034!                                               !            !       !
 !--] [-+                                               !STARTING REG!       !
 !DRUM RESET                                            !HR0150      !       !
 !IN0001                                                !            !       !
 !--] [-----------------------------------------------!            !       !
 !                                                      !            !       !
 !IN0001                                                !            !       !
 !--] [-----------------------------------------------!STEP POINTER!       !
 !                                                      !HR0170      !       !
 !                                                      !            !       !
 !                                                      !DESTINATION !       !
 !                                                      !OG0002      !       !
 !                                                      !            !       !
 !                                                      +------------+       !
0!                                                      +------------+       !
0!TT0010 IN0010                                         !            !DR0012! TIMER
0!--] [-+--]\[-------------------------------------------!NO. OF STEPS!--( )-! DRUM
7!      !                                               !  0009      !       !
 !CR0034!                                               !            !       !
 !--] [-+                                               !STARTING REG!       !
 !                                                      !HR0250      !       !
 !IN0001                                                !            !       !
 !--] [-----------------------------------------------!            !       !
 !DRUM RESET                                            !            !       !
 !IN0001                                                !            !       !
 !--] [-----------------------------------------------!STEP POINTER!       !
 !                                                      !HR0270      !       !
 !                                                      !            !       !
 !                                                      !DESTINATION !       !
 !                                                      !OG0005      !       !
 !                                                      !            !       !
 !                                                      +------------+       !
0!                                                      +------------+       !
0!IN0001                                                !            !MV0052! TIME VALUE
0!--] [-----------------------------------------------!SOURCE      !--( )-! INTO TIMER
8!                                                      !OG0005      !       !       REGISTER
 !                                                      !            !       !
 !                                                      !DESTINATION !       !
 !                                                      !HR0100      !       !
 !                                                      !            !       !
 !                                                      +------------+       !
 !                                                                  END      !
 !                                                                           !
```

WESTINGHOUSE NUMA-LOGIC REGISTER PRINTOUT V5.0 0001 REF. NO. 0000

| | | | | |
|---|---|---|---|---|
| HR0150 | 0001 | 0000 | 0010 | 1000 |
| HR0151 | 0000 | 0000 | 0001 | 0000 |
| HR0152 | 0000 | 0000 | 0000 | 0100 |
| HR0153 | 0000 | 0000 | 0000 | 0101 |
| HR0154 | 0000 | 0000 | 0000 | 0111 |
| HR0155 | 0100 | 0000 | 0100 | 0111 |
| HR0156 | 0000 | 0000 | 0000 | 0101 |
| HR0157 | 0000 | 0000 | 0000 | 0100 |
| HR0158 | 0000 | 0001 | 0000 | 1000 |
| HR0159 | 0000 | 0000 | 0000 | 0000 |

WESTINGHOUSE NUMA-LOGIC REGISTER PRINTOUT V5.0 0001 REF. NO. 0000

| | | | | |
|---|---|---|---|---|
| HR0250 | 0000 | 0000 | 0010 | 1000 |
| HR0251 | 0000 | 0000 | 0010 | 1000 |
| HR0252 | 0000 | 0000 | 0010 | 1000 |
| HR0253 | 0000 | 0000 | 0010 | 1000 |
| HR0254 | 0000 | 0000 | 0010 | 1000 |
| HR0255 | 0000 | 0000 | 0010 | 1000 |
| HR0256 | 0000 | 0000 | 0010 | 1000 |
| HR0257 | 0000 | 0000 | 0010 | 1000 |
| HR0258 | 0000 | 0000 | 0010 | 1000 |
| HR0259 | 0000 | 0000 | 0010 | 1000 |

WESTINGHOUSE PLC 900/BRAT 801 CODING FORM

| STEP | REGISTER # | TIMER VALUE | RIGHT STA 5 | < | - | > | LEFT STA 1 | AUX | AUX | AUX | ROLL GRIP | SLIDE RIGHT | SLIDE LEFT | ROTATE CCW | ROTATE CW | EXTEND ARM | RAISE ROBOT | GRIP CLOSE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 150 | 4 | | | | 1 | | | | | | | 1 | | 1 | | | |
| 1 | 151 | 4 | | | | | | | | | | | | 1 | | | | |
| 2 | 152 | 4 | | | | | | | | | | | | | | 1 | | |
| 3 | 153 | 4 | | | | | | | | | | | | | | 1 | | 1 |
| 4 | 154 | 4 | | | | | | | | | | | | | | 1 | 1 | 1 |
| 5 | 155 | 4 | | 1 | | | | | | | | 1 | | | | 1 | 1 | 1 |
| 6 | 156 | 4 | | | | | | | | | | | | | | 1 | | 1 |
| 7 | 157 | 4 | | | | | | | | | | | | | | 1 | | |
| 8 | 158 | 4 | | | | | | | | 1 | | | | | 1 | | | |

The illustrated robot could be supplied with a PC control package built in by the robot manufacturer. The next section illustrates how to use your own PC to interface with the robot shown.

## CREATING A PC ROBOT CONTROL SYSTEM

Before programming the PC to control the robot, you must develop a scheme to connect and interface with PC with the robot. Figure 22-8 shows the pin connections to the robot and the necessary color code/wire numbers of the connecting cable. Since the robot uses 110 volts, you need a 110 volt interface I/O for PC inputs and outputs. If you connect the ground, and group common connections by direct wiring, the PC needs only 13 output ports. You therefore would choose a 16-output PC output module.

**Figure 22-8**
Robot Control Cable Pin

Below is a listing of the I/O numbers and the letter that corresponds to the I/O on the cable between the I/O rack and control panel designed for the PC. Also listed are the robot pin # and the corresponding function.

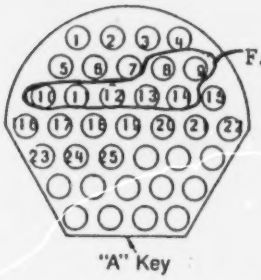
| PC Input # | Cable Letter | Robot Pin # | Robot Function |
|---|---|---|---|
| 1 | A | — | — |
| 2 | B | — | — |
| 3 | C | — | — |
| 4 | D | — | — |
| 5 | E | — | — |
| 6 | F | — | — |
| 7 | G | — | — |
| 8 | H | 22 | Aux. Input |
| 9 | J | 23 | Aux. Input |
| 10 | K | 24 | Aux. Input |
| 11 | L | 25 | Aux. Input |
| 12 | M | 2 | Station 1 Left |
| 13 | N | 3 | Station 2 |
| 14 | P | 4 | Station 3 |
| 15 | Q | 5 | Station 4 |
| 16 | R | 6 | Station 5 |
| | S | 7 | Common Input |

| PC Output # | Cable Letter | Robot Pin # | Robot Function |
|---|---|---|---|
| 17 | T | 8 | Grip |
| 18 | U | 10 | Elevate |
| 19 | V | 15 | Extend |
| 20 | W | 11 | Rotate CW |
| 21 | X | 12 | Rotate CCW |
| 22 | Y | 13 | Slide Left |
| 23 | Z | 14 | Slide Right |
| 24 | a | 9 | Rotate Grip |
| 25 | b | 19 | Aux. Output |
| 26 | c | 20 | Aux. Output |
| 27 | d | 21 | Aux. Output |
| 28 | e | — | — |
| 29 | f | — | — |
| 30 | g | — | — |
| 31 | h | — | — |
| 32 | j | — | — |
| | k | 16 | Common Output |

CABLE PIN ASSIGNMENT

| CONTACT NO. | PIN NO. | FUNCTION | WIRE COLOR |
|---|---|---|---|
| 1 | 1 | GROUND | GREEN |
| 2 | 2 | STATION 1 | WHITE |
| 3 | 3 | STATION 2 | ORANGE |
| 4 | 4 | STATION 3 | BLUE |
| 5 | 5 | STATION 4 | RED |
| 6 | 6 | STATION 5 | BLACK |
| 7 | 7 | COMMON | WHT/RED |
| 8 | 8 | GRIP | ORG/GRN |
| 9 | 9 | GRIP ROTATE | GRN/WHT |
| 10 | 10 | ELEVATION | RED/WHT |
| 11 | 11 | ROTATE CLOCKWISE | ORG/RED |
| 12 | 12 | ROTATE CCW | BLUE/RED |
| 13 | 13 | SLIDE LEFT | RED/BLK |
| 14 | 14 | SLIDE RIGHT | BLUE/WHT |
| 15 | 15 | ARM EXTENSION | BLK/RED |
| 16 | 16 | COMMON | GRN/WHT/BLK |
| 17 | 17 | INTERLOCK | RED/WHT/BLK |
| 18 | 18 | INTERLOCK | WHT/BLK |
| 19 | 19 | Microbot In #3 | ORG/BLK |
| 20 | 20 | SPARE CONTACTS | WHT/RED/BLK |
| 21 | 21 | | BLK/WHT |
| 22 | 22 | | BLUE/BLK |
| 23 | 23 | | GRN/BLK |
| 24 | 24 | Microbot Out #1 | BLK/RED/WHT |
| 25 | 25 | | RED/GRN |

110V. for switches




Microbot Input #

*NOTE: CONTACTS #8,9,10,11,12,& 14 PASS THROUGH THE FAULT PANEL.

*NOTE: CONTACTS #19 THRU 25 ARE SPARE CONTACTS AND CAN BE USED FOR PERIFERIAL EQUIPMENT OR OPTIONAL MODULES TO BE CONTROLLED AND PROGRAMMED BY THE CONTROL CONSOLE.

Pins 13 & 14 are crossed.

## MICROBOT PROGRAM WITH INTERFACE I/O

0 HOME
1 Move to wait point
2 Jump 3,1 (Causes program to loop until PLC activates Microbot movement.)
3 Out #1 (Initiates hold so that the Pneumatic cannot move.)
4 Move above part.
5 Open grip.
6 Get part.
7 Close grip.
8 Raise part.
9 Move part to new position.
10 Down.
11 Open.
12 Up.
13 Out #1 off. (Allows Pneumatic robot to move.)
14 Jump 9,1 (Moves robot to wait point.)

### Microbot I/O

Microbot Out #1 = PLC Input #10

Microbot Input #3 = PLC Out #25